the speed and capacity of connections are increasing, and more people are obtaining wireless connections. See sidebar, “Wireless Networking.”

Applications of IT

A fourth trend is the ever-increasing array of applications that make IT more useful. Computers were originally used primarily for data processing. As they became more powerful and convenient, applications expanded. Word processing, spreadsheets, and database programs were among the early minicomputer and PC applications. Over the past two decades, innovations in software have enabled applications to expand to include educational software, desktop publishing, computer-aided design and manufacturing, games, modeling and simulation, networking and communications software, electronic mail, the World Wide Web, digital imaging and photography, audio and video applications, electronic commerce applications, groupware, file sharing, search engines, and many others. The growth and diversity of applications greatly increase the utility of IT, leading to its further expansion.

In the 1960s, computers were used primarily in the R&D community and in the offices of large companies and agencies. Over the past few decades, the expansion of applications has contributed to the rapid diffusion of IT to affect nearly everyone, not just the relatively few people in computer-intensive jobs. IT has become common in schools, libraries, homes, offices, and businesses. For example, corner grocery stores use IT for a variety of electronic transactions such as debit and credit payments, and automobile repair shops use IT to diagnose problems and search for parts from dealers. New IT applications are still developing rapidly; for example, instant messaging and peer-to-peer communication systems such as Napster are examples that have become popular in the past 2 years. See sidebar, “Peer-to-Peer Applications.”

Societal Implications

In contrast to the steady and rapid advances in semiconductor technology, information storage, networking, and applications, the interaction of IT with various elements of society is more complex. Although IT performance in many cases improves exponentially, the utility to users in many cases improves more slowly (Chandra et al. 2000). For example, a doubling of computer processing speeds may bring only small improvements in the most widely used applications, such as word processing or spreadsheets. Furthermore, although it is common to talk about the “impact” or “effect” of IT or the Internet—implying a one-way influence—the interaction of IT with society is multidirectional and multidimensional. Over the past two decades, many studies have explored how organizations use IT. Cumulatively, these studies have found that a simple model of IT leading to social and organizational effects does not hold (Kling 2000). Instead, IT is developed and used in a social context in which organizations and individuals shape the technology and the way it is used. The implementation of IT is an ongoing social process that involves

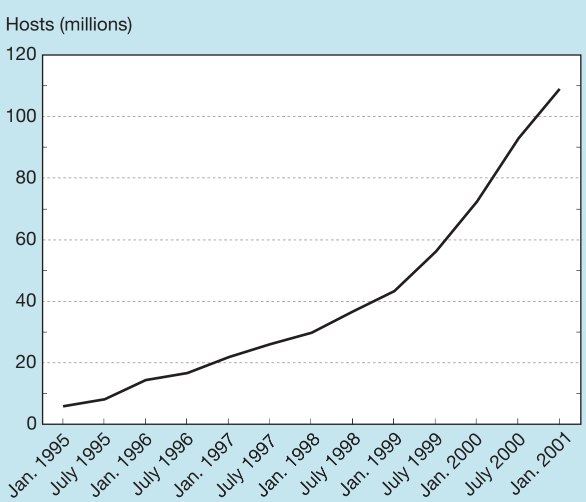
Nanoscale Electronics

As miniaturization proceeds, it may lead to the emergence of nanoscale devices (devices with structural features in the range of 1 to 100 nanometers). The International Technology Roadmap for Semiconductors (2000) projects semiconductor manufacturing to approximately 2010, at which time semiconductors are expected to have 0.1-micron (100-nanometer) structures. Beyond this, the principles, fabrication methods, and ways of integrating devices into systems are generally unknown. Potential applications of nanoscale electronics 10–15 years in the future include (National Science and Technology Council 2000):

- microprocessor devices that continue the trend toward lower energy use and cost per gate, thereby improving the efficacy of computers by a factor of millions;
- communications systems with higher transmission frequencies and more efficient use of the optical spectrum to provide at least 10 times more bandwidth, with consequences for business, education, entertainment, and defense;
- small mass storage devices with capacities at multiterabit levels, 1,000 times better than today; and
- integrated nanosensor systems capable of collecting, processing, and communicating massive amounts of data with minimal size, weight, and power consumption.

Such advances would continue to expand the cost effectiveness and utility of IT in new applications.

Figure 8-4.
Internet domain survey host count worldwide



SOURCE: Internet Software Consortium (<http://www.isc.org>).

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Metcalfe's Law

Metcalfe's Law states that the value of a network grows in proportion to the square of the number of users (Metcalfe 1996; and Downes, Mui, and Negroponte 1998). Just as the value of a telephone to a user depends on the number of other people who also have a telephone, the value of being on a computer network depends on how many other people are also on the network. As a network grows, its value to each individual user increases, and the total value of the network increases much faster than the number of users. This is also referred to as "network effects."

Technologies other than telecommunications also exhibit network effects. The value of owning a certain type of word processing software, for example, depends on how many other people use the same (or at least compatible) software to share files. A more widely used technology also becomes more valuable because more people are trained to use or service it. The more valuable a technology becomes, the more new users it will attract, increasing both its utility and the speed of its adoption by still more users.

Metcalfe's Law explains why the adoption of a technology often increases rapidly once a critical mass of users is reached and the technology becomes increasingly valuable. Because many technology developers are now aware of this phenomenon, initially they often heavily subsidize technologies that exhibit network potential to attain a critical mass of users. The Internet has been the most dramatic demonstration of Metcalfe's Law. Many Internet-related services also exhibit network effects, and many companies have heavily discounted their services in hopes of later being able to capitalize on the value of the network they have created.

The presence of network effects has implications for antitrust law. It implies that markets with strong network effects may tend toward monopoly, as the dominant technology becomes more valuable and the less widely used technology becomes less valuable (even if it is technically superior). It also may become more difficult for new entrants to become established if they need to compete with an established network.

changes in people's roles and in organizational procedures. Incentives and trust are important factors in the success of IT implementation. The following sections examine the effects of IT on the economy and the general public.

Economic Implications

Over the past two decades, there has been considerable debate over the extent to which IT is transforming the economy. Businesses have invested heavily in IT in anticipation of large productivity increases and economic transformations. Only recently, however, have economists found evidence of sector- or economywide IT-related productivity increases, and the question of whether the productivity gains are distributed across the economy or concentrated in the IT sector is still under debate (U.S. DOC 2000a; Council of Economic Advisers 2001).

Although topics such as the expansion of e-commerce and the stock market valuation of Internet companies have received much recent attention, these are only surface manifestations of the role of IT in the economy. This role is both broad and deep and involves changing the composition of the economy, changing productivity (primarily in traditional businesses), and changing both the nature of work and the needs of the workforce. This section outlines these changes.[3]

IT Applications in Business

Businesses have invested heavily in IT. The purchase of IT equipment continues to be the largest category of industry spending for all types of capital equipment (including industrial, transportation, and others). In current dollars, industry spending on IT equipment and software rose from less than $200 billion in 1993 to more than $600 billion in 2000. (See figure 8-7.)

Businesses use IT in many different ways. Some IT applications automate a variety of basic business activities, from production control systems in manufacturing to word processing and financial calculations in office work. Other applications involve databases and information retrieval that support management, customer service, logistics, product design, marketing, and competitive analysis. Through IT, companies can combine computing and communications to facilitate ordering and product tracking. IT functions often are implemented as mechanizations of older, manual processes; ideally, however, they involve fundamental redesign of processes. The use of IT by business began with and in many instances continues to rely on mainframe computers, minicomputers, and microcomputers, as well as telephone networks including the public switched network and leased-line private networks.[4]

More recently, the business community has begun to broaden integration of IT-based systems and, through them, integration of enterprises. The spread of Internet technology and the proliferation of portable computing and communications devices have accelerated trends that began in the past two decades and now are viewed as "electronic commerce" or e-commerce. Companies now use the World Wide Web to communicate with the general public and also use similar but more secure intranets and extranets to communicate with employees, suppliers, and distribution partners.

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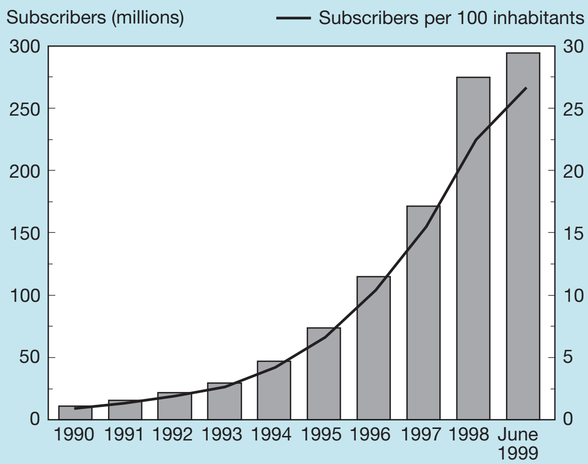
[3]A major U.S. Government source of information on IT and the economy is the *Digital Economy,* a series of reports published by the U.S. DOC's Economics and Statistics Administration. The 2001 edition of the *Economic Report of the President* (Council of Economic Advisers 2001) also focuses extensively on the role of IT in the economy.

[4]Businesses now also rely on virtual private networks, which use the open, distributed infrastructure of the Internet to transmit data between corporate sites, with encryption and other security measures to protect the data against eavesdropping and tampering by unauthorized parties.

Wireless Networking

At present, most people in the United States connect to the Internet through wires. Much of the growth in Internet connections, however, is expected to be through wireless connections. Currently, more people around the world have mobile phones than Internet access. Figure 8-5 shows the growth in mobile phone subscribers in Organisation for Economic Co-operation and Development (OECD) countries; figure 8-6 shows mobile phone penetration in individual OECD countries.

Figure 8-5.
Mobile phone subscriber growth in OECD countries: 1990–99



OECD = Organisation for Economic Co-operation and Development

See appendix table 8-3.

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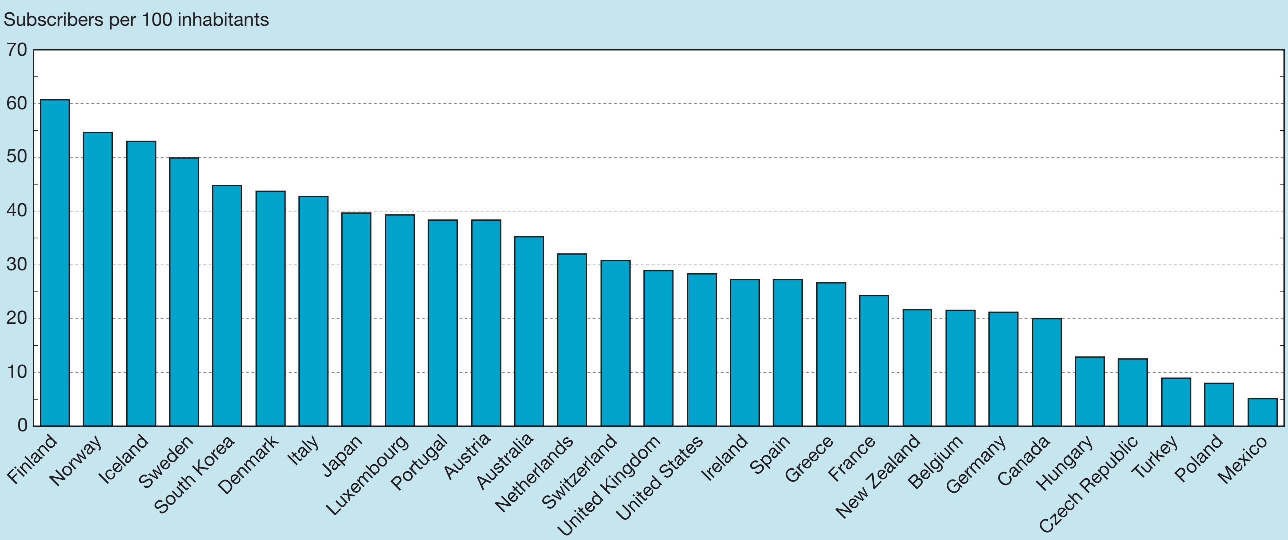
Over the next few years, most mobile phones will obtain Internet access (Wong and Jesty 2001). By 2005, the penetration level of mobile devices (including phones) with data capabilities is expected to approach mobile phone user penetration levels in the United States, Western Europe, and Japan. It is expected that, by then, all mobile terminals will be data enabled and subscribers will be able to access data and Internet services via mobile phones. As a result, it is likely that in many areas of the world where there are more mobile phone users than personal computer users, more people will have access to the Internet through mobile phones than through computers. International Data Corporation estimates that the number of wireless Internet subscribers in the United States, Western Europe, Asia/Pacific, and Japan will increase from 5 million in 1999 to more than 329 million by 2003 (Wrolstad 2001). Mobile Internet usage is growing particularly fast in Japan, primarily because of the popularity of the relatively low-cost NTT DoCoMo "I-mode" phones, which are being widely used for e-mail and games.

Because of the relatively small screen size, limited memory, and weak data entry capabilities of mobile phones, Internet access through mobile phones is qualitatively different from access through computers. Efforts are under way to determine what applications will work effectively over mobile phones. Successful mobile applications are likely to differ from typical computer-based applications. In addition to limited e-mail and Web browsing capabilities, mobile phones may also offer various location-based services, such as information on restaurants, shops, and services in the vicinity of the phone's current location.

Figure 8-6.
Mobile phone penetration in OECD countries: June 1999



OECD = Organisation for Economic Co-operation and Development

See appendix table 8-3.

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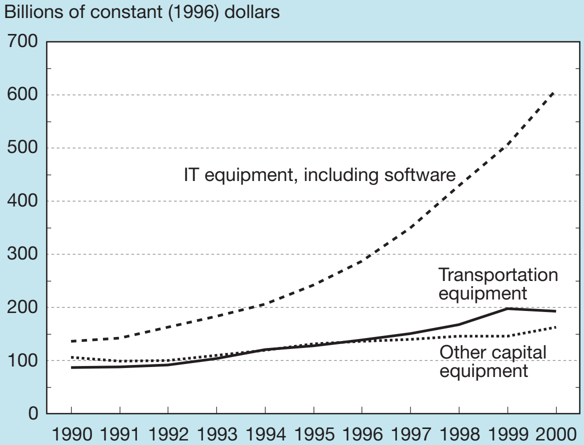
Figure 8-7.
Industry spending on capital equipment



SOURCE: Bureau of Economic Analysis. Available at http://www.bea.doc.gov/bea/dn/nipaweb/

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Growth of e-Commerce

The growth of e-commerce has changed the focus of the discussion of IT's role in the economy. Previously, the focus had been on how IT applications within companies could improve internal operations. With the growth of e-commerce, the focus has shifted to how businesses are using IT to communicate with customers and suppliers and develop new distribution chains and new methods of marketing and selling.

Definitions of e-commerce vary. The U.S. Census Bureau (Mesenbourg 2001) defines e-commerce as the value of goods and services sold on-line, with "on-line" including the use of the Internet, intranets, extranets, and proprietary networks that run systems such as electronic data interchange (EDI). Other definitions include only transactions that use open (generally Internet-based) systems rather than proprietary electronic systems.

E-commerce includes both business-to-business transactions and business-to-consumer transactions. The following sections summarize developments in these two areas.

Business-to-Business e-Commerce. Although business-to-consumer e-commerce has attracted more public attention, electronic transactions between businesses are much larger in volume. Because business-to-business e-commerce is built on the history of pre-Internet electronic transactions, many companies have substantial relevant expertise already in place. As a result, business-to-business e-commerce has expanded rapidly.

The U.S. Census Bureau (2001b) has produced estimates of 1999 e-commerce activity for several sectors of the economy. In manufacturing, e-commerce shipments accounted for 12.0 percent of the total value of shipments or $485 billion. For merchant wholesalers, e-commerce sales represented 5.3 percent of total sales or $134 billion. The Census Bureau estimates that approximately 90 percent of e-commerce transactions are business to business rather than business to consumer. The U.S. Census Bureau (2001b) also suggests that the manufacturing sector has a higher rate of e-commerce than other sectors because manufacturing firms (especially large ones) have been using private data networks for business-to-business transactions for many years.

Private estimates of business-to-business e-commerce in 2000 and 2004 are shown in text table 8-1. The private estimates vary in part because each firm uses somewhat different definitions. Despite the slowdown in the economy in 2001, many analysts still forecast continued growth for business-to-business e-commerce (Thompson 2001).

Business-to-business e-commerce enables businesses to offer their customers additional services and the means to improve communication. By improving communication, business-to-business e-commerce makes it possible for businesses to outsource more easily and to streamline and augment supply chain processes. It also allows businesses to eliminate

Peer-to-Peer Applications

A new class of applications known as peer-to-peer (P2P) services have become widely used. These applications take advantage of computing resources, such as storage, processing cycles, and content, available at the "edge" of the Internet, and include computers that are only temporarily connected to the Internet (Shirky 2000). In its early days, the Internet primarily connected computers at research institutions, and these computers shared resources on a fairly equal basis. Since the advent of the World Wide Web, the Internet has evolved into a client-server architecture, in which client computers connect to the Web primarily to download information. Many client computers are not permanently connected to the Web, do not have permanent Internet Protocol (IP) addresses, and thus are not available for other computers to access. P2P services provide a way for these computers to be available to others on the Internet.

The most widely known of the P2P services is Napster. Founded in 1999 by Shawn Fanning, then an 18-year-old college freshman, Napster enables users to find and access music files that are available on other users' computers. By March 2001, the Napster service had grown to the point where it was accessed by more than 4 million individual users each day (defined by unique IP addresses) and consistently had up to 500,000 concurrently active users (Napster 2001). Because Napster made it possible for people to share and copy copyrighted information, it has also raised some substantial intellectual property concerns. As a result of litigation, Napster has been required to remove copyrighted material from its network.

Many other less visible and less controversial P2P applications have been developed, including applications that let people access computer-based information across companies or government agencies, and applications that use idle computers to carry out complex scientific calculations (Ante, Borrus, and Hof 2001).

Text table 8-1.
U.S. business-to-business e-commerce estimates and forecasts: 2000 and 2004
(Billions of dollars)

Firm	Study date	2000	2004
Boston Consulting Group	September 2000	1,200	4,800
Forrester Research	February 2000	406	2,696
Gartner Group	March 2001	255	3,600
Giga Information	December 2000	957	3,804
International Data Corporation (IDC)	April 2001	117	1,000
Jupiter Research	September 2000	336	4,592
Yankee Group	April 2000	740	2,780

NOTE: Each firm listed defines business-to-business e-commerce differently.

SOURCE: *The Industry Standard*. Available at <http://www.thestandard.com/article/image/popup/0,1942,15847-15845-15846-15848,00.html>. Accessed August 19, 2001.

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some intermediary organizations between customers and suppliers but has also has given rise to new classes of business intermediaries, such as on-line auctions.

These new intermediaries can provide new places for buyers and sellers to meet, allow a variety of pricing schemes to flourish, alter the roles of traditional intermediaries, facilitate complex transactions, and shift the balance of power among market participants by making vast amounts of information available at very low costs (U.S. DOC 2000a). These on-line marketplaces enable buyers to solicit bids from a broader range of suppliers and allow suppliers to develop relationships with more buyers. In many cases, however, it is not yet clear how well these new intermediaries will work, in part because they do not replace certain functions such as the establishment of personal relationships based on trust found in traditional forms of business interaction.

The on-line marketplaces under development in the automotive industry exemplify this emerging form of business-to-business e-commerce. In February 2000, General Motors Corporation, Ford Motor Company, and Daimler Chrysler launched the e-business exchange Covisint in an attempt to consolidate their $600 billion in purchasing power, gain efficiencies, and lower costs (U.S. DOC 2000a). The Federal Trade Commission investigated the exchange because of antitrust concerns, and growth has been slower than expected (Welch 2001). The automobile industry has launched other exchanges similar to Covisint. In other examples, Sears, Roebuck and Company is joining with Carrefour SA, a Paris-based retailer, to create GlobalNetXchange, an on-line marketplace for the retail industry, and Boeing, Lockheed Martin, BAE Systems, and Raytheon Company plan to develop an Internet trading exchange for the global aerospace and defense industry (U.S. DOC 2000a).

Business-to-Consumer e-Commerce. Business-to-consumer (or retail) e-commerce has spawned many new businesses that have no physical stores but can deliver a wide variety of goods on request. In response, many traditional retail stores have launched their own e-commerce strategies.

Retail e-commerce sales are still modest. The U.S. Census Bureau (2001a) reported 2000 retail e-commerce sales to be $27.3 billion. In 1999, (the latest year for which detailed information is available) 76 percent of e-commerce sales were in North American Industry Classification System (NAICS) code 454110—Electronic Shopping and Mail-Order Houses. Text table 8-2 shows NAICS 454110 sales data by merchandise category. The two leading categories, computer hardware and books and magazines, account for approximately 50 percent of the NAICS 454110 total e-commerce sales.

The Census Bureau quarterly estimates of retail e-commerce sales are shown in figure 8-8. These estimates encompass sales of goods and services over the Internet, extranets, EDI networks, and other on-line systems. In these transactions, payment may or may not be made on-line. The figures include only retail firms and do not include on-line travel services, financial brokers and dealers, or ticket sales agencies, all of which are not classified as retail.

One mode of retail e-commerce that has expanded rapidly is the on-line auction, which puts buyers and sellers directly in touch with each other to negotiate a price. As of April 2001, eBay (one of the first and largest on-line auction enterprises) offered more than 5 million items for sale. During 2000, the value of goods traded on the eBay site was more than $5 billion (eBay 2001).[5] Hundreds of other on-line auction enterprises have been established, and many early e-commerce retailers such as Amazon.com and Dell Computer have added auctions as additional features of their websites.

IT Effects on Productivity and Economic Growth

As the IT sector has grown faster than the economy as a whole, its share of the economy has increased. (See figure 8-9.) IT also is commonly credited as being a key factor in the economy's structural shift from manufacturing to services. The widespread diffusion of IT is largely responsible for the growth in existing services (such as banking) and the creation of new service industries (such as software engineering) (Computer Science and Telecommunications Board (CSTB) 1994a; Link

[5]These sales are not captured in the Census Bureau figures, which only include sales from e-marketplaces that take title to the goods they sell. Generally, most e-marketplaces arrange for the purchase or sale of goods owned by others and do not take title to the goods they sell (U.S. Census Bureau 2001c).

Text table 8-2.
Electronic shopping and mail-order house total (NAICS 454110) and e-commerce sales by merchandise line: 1999

Merchandise Items	Sales (millions of dollars) Total	Sales (millions of dollars) E-commerce	E-commerce percentage of total sales	Percent distribution E-commerce	Percent distribution Total
Total sales	93,149	11,733	12.6	100.0	100.0
Books and magazines	3,611	1,631	45.2	13.9	3.9
Clothing and clothing accessories (including footwear)	12,363	757	6.1	6.5	13.3
Computer hardware	25,098	4,336	17.3	37.0	26.9
Computer software	2,484	760	30.6	6.5	2.7
Drugs, health aids, and beauty aids	10,362	258	2.5	2.2	11.1
Electronics and appliances	2,258	399	17.7	3.4	2.4
Food, beer, and wine	1,540	230	14.9	2.0	1.7
Furniture and home furnishings	5,494	240	4.4	2.0	5.9
Music and videos	4,490	809	18.0	6.9	4.8
Office equipment and supplies	7,502	600	8.0	5.1	8.1
Toys, hobby goods, and games	2,052	391	19.1	3.3	2.2
Other merchandise[a]	14,723	966	6.6	8.2	15.8
Nonmerchandise receipts[b]	1,173	356	30.3	3.0	1.3

[a]Merchandise such as jewelry, sporting goods, collectibles, souvenirs, auto parts and accessories, hardware, and lawn and garden supplies.

[b]For example, auction commissions, shipping and handling, customer support, and online advertising.

NOTES: Details may not add to totals because of rounding. Data are grouped according to merchandise categories used in the *Annual Retail Trade Survey.* North American Industrial Classification System (NAICS) 454110, "Electronic shopping and mail-order houses" comprises businesses primarily engaged in retailing all types of merchandise through catalogs, television, and the Internet. Data are preliminary and subject to revision.

SOURCE: U.S. Bureau of the Census. *1999 Annual Retail Trade Survey.*

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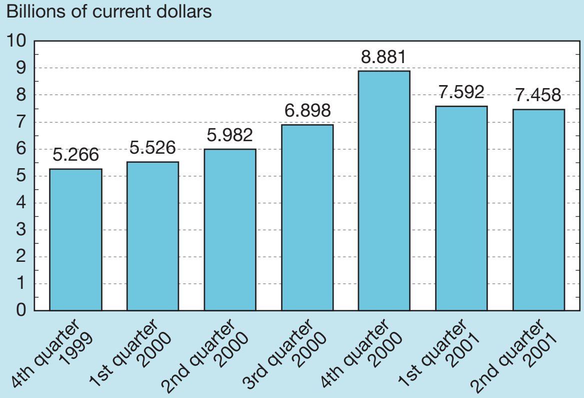
Figure 8-8.
Estimated quarterly U.S. retail e-commerce sales: 4th quarter 1999–2nd quarter 2001



NOTE: Data are not adjusted for seasonal, holiday, or trading day differences.

SOURCE: U.S. Department of Commerce. Available at <http://www.census.gov/mrts/www/current.html>

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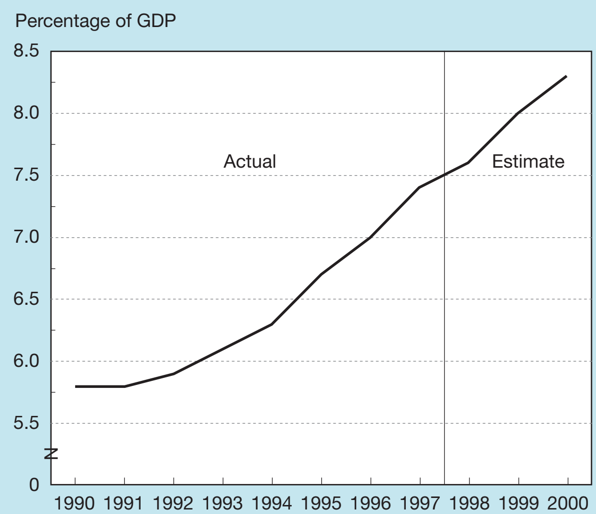
Figure 8-9.
Economy share of IT-producing industries



GDP = gross domestic product

SOURCE: U.S. Department of Commerce, Economics and Statistics Administration, 2000. *Digital Economy 2000*. Washington, DC.

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and Scott 1998). In addition to its role in changing the structure of the economy, IT affects productivity and economic growth overall, as discussed in the following sections.

The Productivity Paradox: Recent Studies. For a long time, little evidence showed that IT had improved productivity in the aggregate. Solow (1987) noted that "we see computers everywhere but in the productivity statistics," an observation that became referred to as the "productivity paradox." Many econometric analyses failed to find any sector- or economywide productivity benefits for IT (for reviews of this literature, see Brynjolfsson and Yang 1996 and CSTB 1994a).

Several explanations have been put forward for the productivity paradox. One explanation involves measurement difficulties. Much of the expected effect of IT would occur in the service industries, where productivity is always difficult to measure. IT may lead to improvements in services that do not readily show up as productivity improvements. Another possibility is that productivity has not increased in the aggregate because it takes time and investment in training for organizations to learn to use IT effectively. Using IT is expensive not only in terms of initial costs but also in terms of the cost to maintain and upgrade systems, train people, and make the organizational changes required for a company to benefit from IT. Such costs may greatly exceed the original investment in IT equipment. Although some companies have successfully made these investments and have greatly benefited, many have not. Another possible explanation is that until the 1990s, business investment in IT was small enough that one would not expect to see a large productivity increase in the overall economy.

In the past few years, however, several studies that have used a variety of approaches have concluded that IT is having a positive effect on productivity (U.S. DOC 2000a; Council of Economic Advisers 2001). Economists who were skeptical about the impact of computers on U.S. productivity have begun to credit IT for increases in the growth rates of output and productivity since 1995. Several studies found that the acceleration in productivity growth during the mid-1990s was attributable largely to increased computer use (capital deepening) among IT users and also to technical advances and innovations by IT producers (U.S. DOC 2000a).

Sector-level studies also suggest that IT investments contribute to productivity growth. U.S. DOC (2000a) found that IT-intensive goods-producing industries have achieved higher productivity gains than their non-IT-intensive counterparts but that the effect of IT on service industry productivity will remain clouded until better output measures are developed.

Recent firm-level analyses also have shown that IT contributes substantially to productivity growth. Brynjolfsson and Hitt (2000, 1998, 1996, 1995) have explored the relationship between computers and productivity growth at the firm level and have found positive correlations between IT and productivity. They also have found that investments in organizational change greatly increase IT's contribution to productivity. Brynjolfsson and Hitt (1998) conclude that although computerization does not automatically increase productivity, it is an essential component of a broader system of organizational change that does.

Inflation and Overall Economic Growth. IT appears to be having positive effects on inflation and growth. These effects derive primarily from price and growth trends in the IT sector rather than from IT applications in other sectors. U.S. DOC (1999a, 2000a) found that declining prices in IT-producing industries have helped to reduce inflation in the economy as a whole. Declining IT costs may also have helped other industries to control their costs. DOC also found that IT-producing industries have contributed substantially to overall economic growth, accounting for more than one-third of the growth in real output between 1995 and 1999.

Outlook for Continued Productivity Growth. Litan and Rivlin (2001) estimated how much the Internet might contribute to productivity increases in the future. In their study, experts in particular sectors of the economy examined how the Internet was being used in leading firms or institutions in these sectors; what the impact on cost, prices, and productivity appeared to be; and how rapidly the Internet's impact might spread to other parts of the sector. See sidebars, "The Internet and Productivity in the Automobile Industry" and "The Internet and Productivity in the Personal Computer Industry." Based on these sector analyses, Litan and Rivlin concluded that the Internet has the potential to add as much as 0.2–0.4 percent a year to productivity. The improvements result from the application of networked computing via the

The Internet and Productivity in the Automobile Industry

The Internet can potentially lead to cost reductions and productivity improvements in the automobile industry in a variety of ways (Fine and Raff 2001). Potential savings can occur in:

- product development (improved ease of making engineering changes, reduced cost of making changes, lower direct cost of communication and coordination, faster product development cycle speed);
- procurement and supply (reduced transaction costs in purchasing, more bulk buying and shipping, more price competition among suppliers, improved logistics and reduced "rush" orders as a result of better information);
- manufacturing system (improved design for ease of manufacture, faster setups, smaller lot sizes, reduced inventory, higher capacity utilization, more outsourcing); and
- vehicle order-to-delivery management (reduced order-to-delivery cycle times, lower inventory levels in pipeline, better matching of supply to demand, less discounting of undesired stock, lower sales commissions, fewer dealers and lower total overhead, fewer distribution centers, and lower shipping costs).

The estimated combined potential for cost reductions in these areas is equivalent to 13 percent of the cost of automobiles. Achieving these savings, however, would require changes in the manufacturing system and supply chain that would be difficult to bring about, and actual cost saving may be much lower. Nevertheless, because the automobile industry is large, achieving only part of these savings could result in measurable productivity changes in the overall economy.

The Internet and Productivity in the Personal Computer Industry*

The personal computer (PC) industry has been closely linked to development of the Internet. The availability of inexpensive PCs has fueled expansion of the Internet, and the Internet, in turn, has driven much of the demand for PCs. It is not surprising that the PC industry has been an early adopter of the Internet as a business tool.

Cutthroat pricing, rapid technological change, global supply and distribution chains, and changing consumer tastes have characterized the PC industry. The modularity of PCs and the availability of components on the open market have led to intense competition at many levels in the industry. No single business and distribution model has dominated the industry, which includes large global players such as Compaq, Hewlett-Packard, and IBM that sell through traditional distribution channels, direct-order marketers such as Dell, and many small companies.

As a strategy for meeting the intense price competition in the PC industry, some manufacturers began to use foreign sources for components and even for finished PCs. However, this tended to lead to having more components tied up in the supply and distribution chain for a longer time. Constant improvements in the cost and performance of semiconductors and disk drives (see figures 8-1 and 8-2) have led to continued and even accelerating improvements in the cost and performance of computers (see figure 8-3). The effect of the price declines of PCs has meant that components and computers depreciate very quickly. In this environment, improving efficiency throughout the supply chain—from component producer to consumer—is extremely important.

The direct-order process whereby customers order computers directly from the manufacturer has great advantages in this respect. Dell, for example, builds its PCs only after they are sold to the consumer, thereby greatly reducing the inventory and risks associated with price reductions and changing consumer tastes. Making the supply chain more efficient became more important as technical change and price reductions accelerated. By 1996–97, the traditional assembly-to-distribution channel marketing system was at a competitive disadvantage to the direct-order marketing model.

The Internet reinforced the competitiveness of direct marketers and increased difficulties for traditional assemblers. It allowed direct marketers to provide better support than was possible through traditional catalog and telephone service. Companies first put technical support information on-line, then let customers configure and price PCs on-line, and finally made it possible for customers to conduct entire transactions on-line. For direct marketers, replacing telephone operators (who were simply conduits for entering orders into a computer) with an Internet-based interface did not represent a great change in technical and business strategy and allowed Internet-based sales to grow quickly.

At Dell, for example, Internet-based sales grew from $1 million per day in December 1996 to $40 million per day by February 2000, equal to 50 percent of total sales. Dell also achieved substantial savings through Internet-based sales transactions. For example, the company estimated that it saved more than $21 million through avoided order status calls in 1999. The Internet also permitted Dell to increase service to its corporate customers and improve communication with its largest suppliers, allowing them to use the Internet to find out Dell's requirements for incoming materials, receive statistics from the company's manufacturing lines, and gather data on the reliability of components supplied.

Traditional computer makers have attempted to emulate aspects of the Internet-based direct-order marketing model. Most have either been slower to implement the model or unable to implement it fully because the model puts them in direct competition with their traditional distribution chains.

Several new startup companies have formed to sell PCs from their websites or to refer customers to assemblers or distributors. Many of the startups, however, have experienced difficulty making a profit, in part because established PC companies were quick to implement Web-based sales and other activities. The startups have added an additional marketing channel but have not transformed the PC industry. The main effect of the Internet on the industry appears to have been the strengthening of the direct-order marketing business model.

*The source for material in this section, unless otherwise noted, is Kenney and Curry (2000).

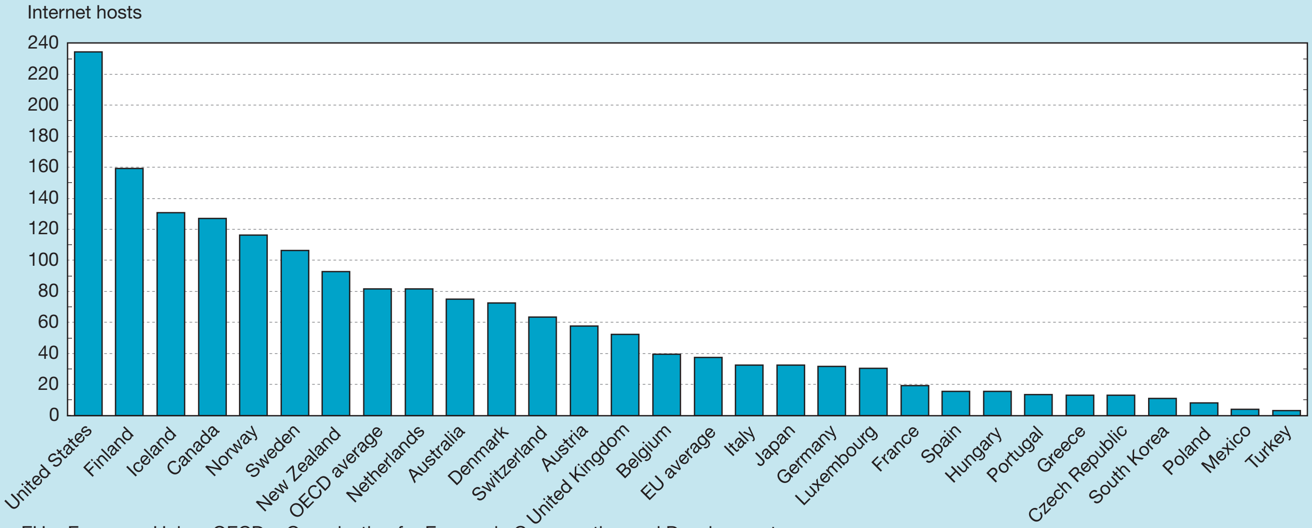
Internet and intranets to business activities carried out in companies devoted to such "old economy" activities as manufacturing, transportation, financial services, and conventional retailing. Major cost savings resulting from Internet use in the government and health sectors also are likely to contribute to overall productivity growth.

IT Effects on Income and Work

IT both creates and eliminates jobs. As jobs are created or eliminated, labor markets adjust in complex ways. Wages go up in areas (occupations or locales) in which the demand for skills exceeds the supply and go down in areas in which there are more jobs than workers. Over time, the effects of IT are likely to appear not in unemployment figures but in the wages of different occupations.

As noted by Katz (2000) in a review of the literature on computerization and wages, many studies have found that education-based wage differentials have increased in the past two decades, coinciding with the computerization of the workplace. The increases in both the wages and relative supply of

Figure 8-10.
Internet hosts, per 1,000 inhabitants in the OECD countries: October 2000



EU = European Union; OECD = Organisation for Economic Co-operation and Development

See appendix table 8-4. *Science & Engineering Indicators – 2002*

educated workers are consistent with the idea that IT allows skilled workers to perform more functions and produce things that previously were in the domain of less skilled workers. This diminishes the “terms of trade” of less skilled workers, thereby reducing their relative income (Johnson and Stafford 1998; Gomery 1994).

Katz (2000) notes that within industries, relative increases in employment and wages during the 1980s and 1990s were greater for workers with more education, an indication of labor market shifts favoring workers with more skills. He also found that skill-related and organizational changes that have accompanied the computer revolution appear to have contributed to faster growth (starting in the 1970s) in the demand for skilled labor. However, factors other than technological change, including a slowdown in the increase of college-educated people entering the labor force, a trend toward globalization (especially outsourcing of low-skilled work to other countries), and a weakening of labor unions, may also contribute to rising wage differentials.

Many people have feared that automation will reduce demands on workers’ conceptual talents and facility with machinery, equipment, and tools. On the other hand, IT can be expected to increase the demand for “knowledge workers” (those who manipulate and analyze information) relative to the demand for workers who do not process information as part of their jobs or those who simply enter and collate data. Case studies of specific industries, occupations, and IT show that IT can in some cases increase and in other cases reduce the level of skill required in particular jobs. (For reviews of such studies, see Attewell and Rule 1994, Cyert and Mowery 1987.) On balance, however, several studies (Autor, Katz, and Krueger 1997; Castells 1996; Berman, Bound, and Griliches 1994; Howell and Wolff 1993) using different data sets and methodologies suggest that no overall deterioration of skills is occurring in the workforce and that upgrading of skills may be widespread.

IT and the Citizenry

IT is part of the fabric of daily life, supporting activities at home, work, and school. This section addresses how IT affects citizens and society. It focuses on three areas: participation in the digital economy, IT applications in the home, and the influence of IT on government’s interaction with its citizenry.

Participation in the Digital Economy

The past few years have seen widespread concern that digital technologies may be exacerbating existing differences in demographic groups’ access to information and, consequently, their ability to participate fully in the information society. The term “digital divide” has been widely used to characterize demographic gaps in effective use of IT. This section begins with a brief summary of Internet access indicators worldwide. It also examines recent data on access to and use of IT (primarily the Internet) by different demographic groups in the United States, including comparisons by income, education, and race/ethnicity. Finally, it looks at Internet access among people with disabilities, reasons people do not use the Internet, and new modes of accessing the Internet.

Global Internet Access. Text table 8-3 shows the growth in Internet hosts in different areas of the world. Although rapid growth continues in much of the world, the international digital divide is still significant, and Africa appears to be falling farther behind. In October 1997, Internet host penetration in North America was 267 times that in Africa; by October 2000, the gap had grown to a multiple of 540.

A wide variation in Internet hosts per 1,000 inhabitants also exists among OECD countries. As shown in figure 8-10 and appendix table 8-4, the United States and Scandinavian countries lead, while such large economies as Germany, Japan, and France are significantly below the OECD average.

A major factor affecting Internet use across countries is telecommunications access charges. As shown in figure 8-11, a

Text table 8-3.
Internet hosts, per 1,000 inhabitants: trends by world region

Region	October 1997	October 1998	October 1999	October 2000
North America	46.28	69.74	116.41	168.68
Oceania	26.81	34.76	43.84	59.16
Europe	6.13	9.45	13.41	20.22
Central and South America	0.48	0.91	1.67	2.53
Asia	0.53	0.87	1.28	1.96
Africa	0.17	0.21	0.28	0.31

SOURCE: Organisation for Economic Co-operation and Development (OECD). 2001. *Understanding the Digital Divide.* Paris. Available at <http://www.oecd.org/dsti/sti/prod/Digital_divide.pdf>.

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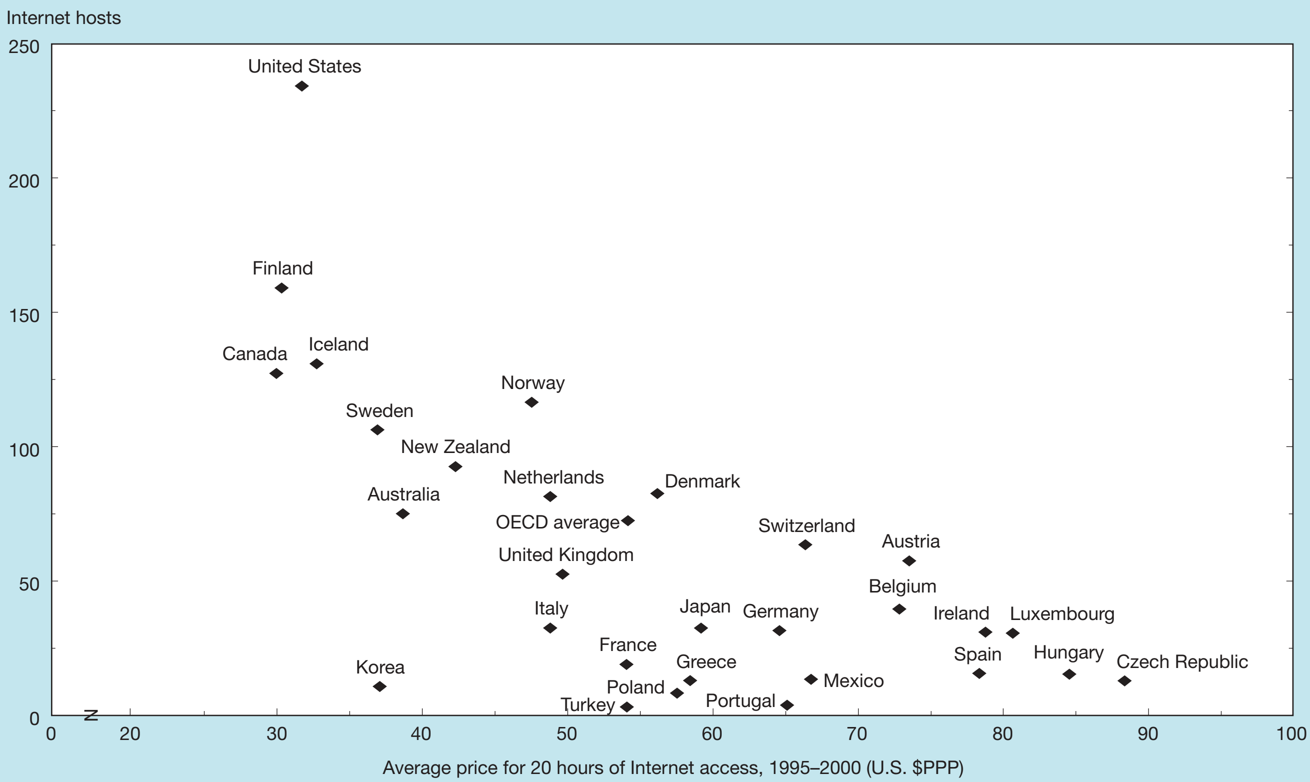
Figure 8-11.
Internet access prices and Internet host penetration per 1,000 inhabitants: October 2000



OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTES: Data on hosts for Luxembourg are from mid-1999. Internet access costs include value-added taxes.

SOURCE: OECD (www.oecd.org/dsti/sti/it/cm) and Telcordia Technologies (http://www.netsizer.com)

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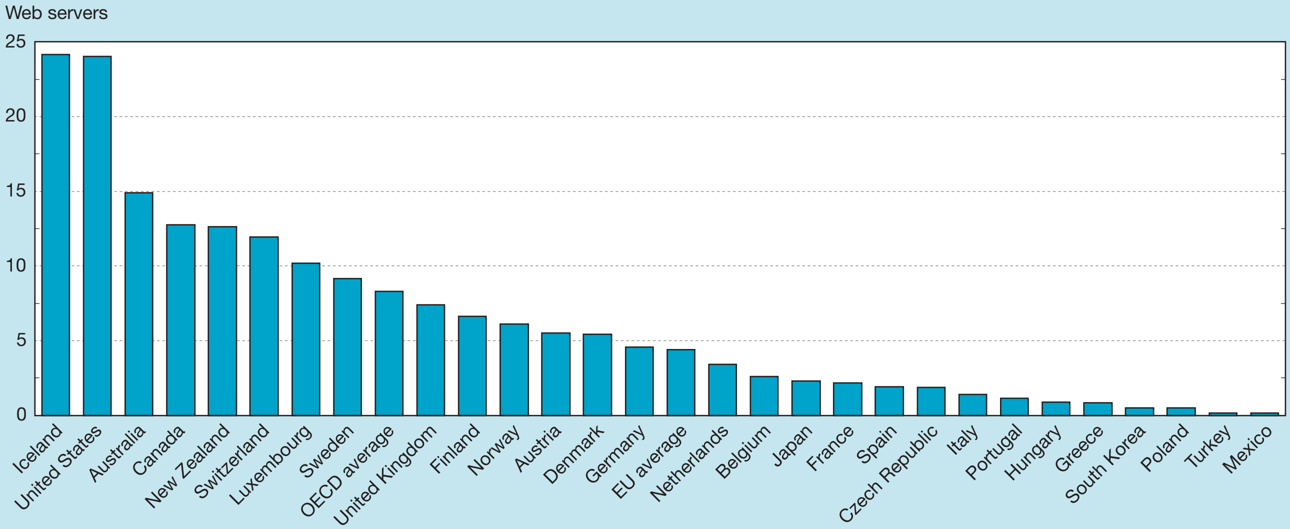
strong correlation exists between the price of Internet access and the number of Internet hosts per 1,000 inhabitants.

Because secure Web servers (those that use encryption and third-party certification) are needed for electronic transactions in both commerce and government, their number and locations are key indicators of the use of networks for business purposes. Figure 8-12 shows the number of secure Web servers per 1 million inhabitants in OECD countries as of July 2000. The United States currently leads by this measure, but servers suitable for e-commerce are dispersing around the globe. As of July 2000, more than 96,000 secure servers were operating in OECD countries—more than four times as many as in July 1998.

Indicators of Participation in the Digital Economy. In the 1980s, households that had PCs were on the cutting edge of IT use; since the mid-1990s, however, access to the Internet has become the primary indicator of a household's IT use. Because the Internet opens information resources to people in ways that unconnected PCs do not, this section emphasizes Internet access more than computer ownership.

In the future, many people may achieve Internet access through interactive televisions, personal digital assistants, and

Figure 8-12.
Secure Web servers per 100,000 inhabitants in OECD countries: July 2000



EU = European Union; OECD = Organisation for Economic Co-operation and Development

SOURCE: Organisation for Economic Co-operation and Development. *Communications Outlook – 2001*. Paris. 2001. Based on data from Netcraft. <http://www.netcraft.com>.

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wireless telephones. However, these technologies may provide considerably less access to information resources than is possible through a computer. Internet access alone ultimately may not be the key measure of ability to participate in the digital economy. It may be necessary to examine the quality of Internet access and how that access is used.

Physical access to technology is not enough to ensure participation in the digital economy (Wilson 2000). People need the kind of educational background that will prepare them to use the technology effectively to find and access information. They also need to be able to process and evaluate the information they find. In addition, the information content must be of use to them; for example, if the Internet offers little content in a person's language, then Internet access offers little benefit to that person.

Research on Home IT Diffusion. The research literature on technological diffusion shows that individuals who are affluent, better educated, and employed in higher status occupations (compared with society as a whole) tend to be early adopters of new technologies. This pattern holds true for all kinds of household products, technologies, and innovations, including PCs and Internet access. Research conducted in the 1980s and 1990s on home IT diffusion found that income and other socioeconomic factors such as education were strong predictors of early PC use (McQuarrie 1989; Dutton, Rogers, and Jun 1987; Riccobono 1986; Dickerson and Gentry 1983). Hoffman and Novak (1998) found complex relationships between home IT access (as measured by ownership of PCs) and race, income, and education. They found gaps in computer ownership that could not be accounted for by differences in income or education. When they controlled for education, they found statistically significant differences in computer ownership between blacks and whites.

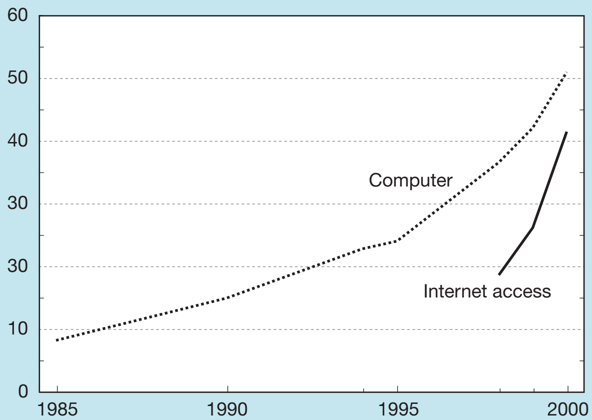
Computer and Internet Access: Recent Data From the Census Bureau's Current Population Survey. Recent data on computer and Internet access, collected by the Census Bureau in a supplement to its August 2000 Current Population Survey (CPS) (U.S. DOC 2000b), are consistent with the research literature. Because CPS is a very large survey (48,000 interviewed) and puts a heavy emphasis on quality, it provides a very reliable measure of computer and Internet access. The survey gathers information on both entire households and individuals within households.[6] Data from similar previous surveys (most recently, December 1998) can be used to identify trends in computer and Internet access.

- ***Overall Trends.*** CPS data show that as of August 2000, more than half of all households (51.0 percent) had computers, up from 42.1 percent in December 1998. (See figure 8-13 and appendix table 8-5.) The share of households with Internet access increased from 26.2 percent in December 1998 to 41.5 percent in August 2000. As of August 2000, 116.5 million Americans were on-line at some location, 31.9 million more than were on-line only 20 months earlier. (See appendix table 8-6.) The share of individuals 3 years or older using the Internet rose by one-third, from 32.7 percent in December 1998 to 44.4 percent in August 2000. (See appendix table 8-7.)

Although Internet access varies by income, education, race/ethnicity, age, and location, access has been increasing across all of these groups.

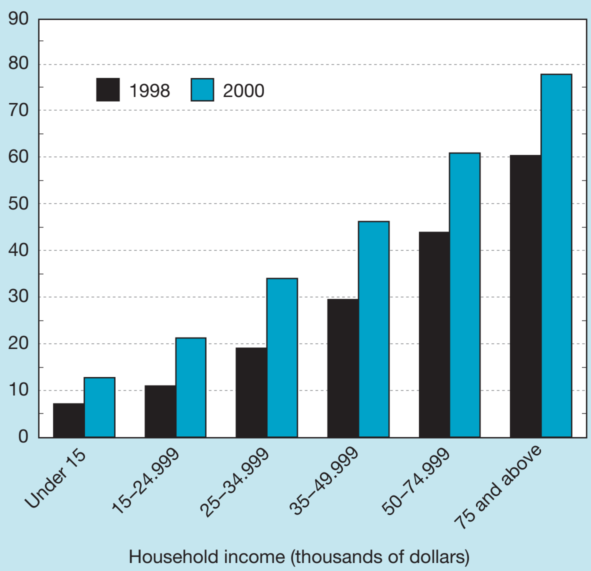
[6] The August 2000 survey gathered information on a total of 121,745 individuals, including children.

Figure 8-13.
U.S. households with a computer and with Internet access



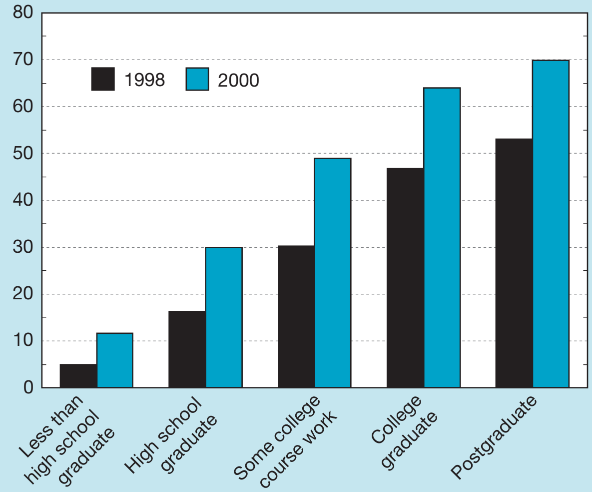
See appendix table 8-5. *Science & Engineering Indicators – 2002*

Figure 8-14.
U.S. households with Internet access, by income: 1998 and 2000



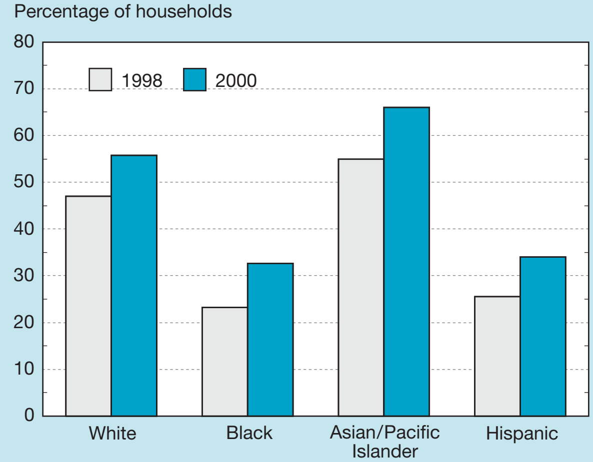
See appendix table 8-6. *Science & Engineering Indicators – 2002*

Figure 8-15.
U.S. households with Internet access by educational attainment of householder: 1998 and 2000



See appendix table 8-6. *Science & Engineering Indicators – 2002*

Figure 8-16.
U.S. households with a computer, by race/ethnicity: 1998 and 2000



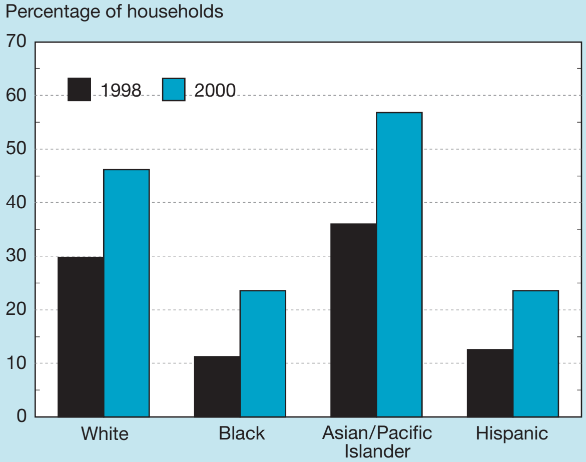
See appendix table 8-5. *Science & Engineering Indicators – 2002*

- ♦ ***Income.*** Figure 8-14 shows the number of households with Internet access, by income level, as of December 1998 and August 2000. It remains highest among households with the highest income, but people at every income level are increasing Internet access at home. More than two-thirds of all households that earn more than $50,000 have Internet connections.

- ♦ ***Education***. Similarly, although people with the highest level of education are most likely to have Internet access, access is also expanding across every education level. (See figure 8-15.)

- ♦ ***Race/Ethnicity.*** As shown in figures 8-16 and 8-17, blacks and Hispanics continue to lag significantly behind whites and Asians/Pacific Islanders in both computer ownership and Internet access. In August 2000, the share of black households that owned computers was 18 percentage points below the national average (32.6 percent for black households compared with 51.0 percent for all households nationally). Similarly, the share of Hispanic households with a computer (33.7 percent) was 17 percentage points below the national average. The share of black and Hispanic households with Internet access was also approximately 18 per-

Figure 8-17.
U.S. households with Internet access, by race/ethnicity: 1998 and 2000



See appendix table 8-6. *Science & Engineering Indicators – 2002*

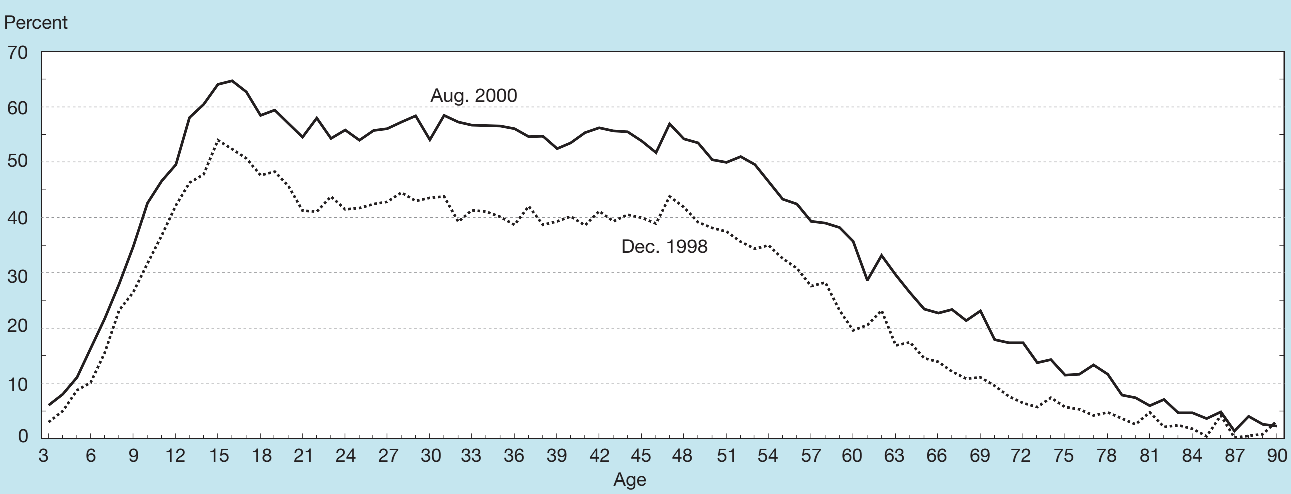
centage points below the national average in August 2000 (23.5 percent for black households and 23.6 percent for Hispanic households, compared with 41.5 percent for all households nationally). U.S. DOC (2000b) found that differences in income and education account for only about half the difference in Internet access among racial/ethnic groups.

Although Internet access is relatively low among black and Hispanic households, growth in access among these households is high. Access more than doubled for black households between December 1998 and August 2000 (from 11.2 percent to 23.5 percent) and also increased significantly for Hispanic households (from 12.6 percent to 23.6 percent). The growth rate in Internet access is higher in black and Hispanic households than in other groups.

- ♦ ***Sex.*** The disparity in Internet access between men and women has largely disappeared. In December 1998, 34.2 percent of men and 31.4 percent of women had home access to the Internet. By August 2000, 44.6 percent of men and 44.2 percent of women had home access.
- ♦ ***Age.*** There were great differences in Internet use among age groups in both December 1998 and August 2000, as shown in figure 8-18. In August 2000, more than 60 percent of teenagers and more than 50 percent of people ages 20–50 used the Internet. Individuals ages 50 and older were among the least likely to use the Internet; however, this age group had the greatest growth in use (compared with December 1998) of all age groups.
- ♦ ***Location.*** Internet access among households in rural areas was similar to access among households nationwide. In rural areas, 38.9 percent of households had Internet access in August 2000 compared with the nationwide rate of 41.5 percent.

Internet Access Among People With Disabilities. As shown in figure 8-19, people with disabilities are only half as likely to have access to the Internet as those without disabilities: 21.6 percent compared with 42.1 percent, respectively. Close to 60 percent of people with disabilities have never used a PC compared with less than 25 percent of people without disabilities. Among people with disabilities, those who have impaired vision and walking problems have lower rates of Internet access than people with other types of disabilities and are less likely to use a computer regularly than people

Figure 8-18
Internet use rates, by age: 1998 and 2000
(Internet use, any location)



SOURCE: U.S. Department of Commerce 2000. *Falling Through the Net: Toward Digital Inclusion, A Report on Americans' Access to Technology Tools*. Washington, DC.

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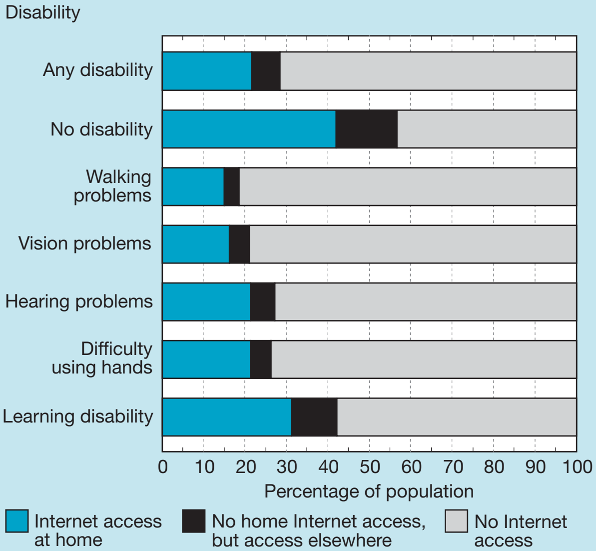
Figure 8-19.
Internet access, by disability: 1999



SOURCE: U.S. Department of Commerce. 2000. *Falling Through the Net: Toward Digital Inclusion, A Report on Americans' Access to Technology Tools*. Washington, DC: U.S. Department of Commerce.

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with hearing difficulties. This difference holds true for all age groups.

Lack of Internet access among people with disabilities is of special concern, because IT has the potential to improve the lives of these people. IT can make working from home more viable for people with limited mobility, turn written material into spoken language for visually impaired people, and turn speech into text for hearing-impaired people. IT does not automatically provide benefits to the disabled, however. Unless technologies are designed carefully, they can create new barriers. For example, websites frequently convey information in a visual form that is inaccessible to people who are visually impaired. Section 508 of the American with Disabilities Act requires that Federal agencies' electronic and information technology is accessible to people with disabilities, including employees and members of the public. This has made millions of Federal webpages more accessible.

The majority of individuals with disabilities are not employed (67.8 percent). Statistical analysis reveals a correlation between the employment status of people with disabilities and their home Internet access and regular use of PCs. The similarity in Internet access and computer use between people with and without disabilities is much greater among employed people than among nonemployed people. For example, among employed people, the rate of Internet access for people with disabilities is 78.3 percent of the rate for people without disabilities; among nonemployed people, that figure is only 46.6 percent.

Reasons for Not Going On-line. Why are some households and individuals not on-line? Lenhart (2001) found that half the adults in the United States do not have Internet access, and 57 percent of those who do not have access are not interested in getting access. This suggests that the booming growth of the U.S. Internet population in the past few years will slow down. Of those without Internet access now, 32 percent say they definitely will not get access, and another 25 percent say they probably will not get access. Among people without Internet access now, people over age 50 are the least likely to say they will go on-line eventually, and younger people are the most likely to say they will. The study also found that 54 percent of those who are not on-line believe the Internet is a dangerous thing, 51 percent say they do not think they are missing anything by staying away from the Internet, 39 percent say the Internet is too expensive, and 36 percent express concern that the on-line world is confusing and hard to negotiate.

DOC has found similar reasons that explain why some people do not have Internet access (U.S. DOC 2000b). Among surveyed households with annual incomes less than $15,000, one-third of respondents without Internet access (32.6 percent) cited cost as the reason and slightly more than one-quarter cited "don't want it" (26.6 percent) as the reason. In contrast, households with incomes greater than $75,000 reversed the order of importance: 30.8 percent cited "don't want it" as the reason for not having Internet access and only 9.4 percent cited cost as the reason.

Some households have discontinued their Internet access. In August 2000, 4.0 million households once had but did not currently have Internet access. That number was essentially unchanged from December 1998, when 4.1 million households reported discontinuing Internet access. In August 2000, the principal reasons cited by households for discontinuing Internet access were "no longer owns computers" (17.0 percent), followed by "can use anywhere" (12.8 percent) and "cost, too expensive" (12.3 percent). Other reasons were "don't want it" (10.3 percent), "not enough time" (10.0 percent), and "computer requires repair" (9.7 percent).

The data about people who have chosen not to have Internet access suggest that this population will remain substantial. However, as computer and telecommunication costs continued to decline and as more services become available over the Internet, some people who currently choose not to have Internet access may change their minds.

New Modes of Access. The digital divide in terms of Internet access among various demographic groups appears to be closing. However, as technology evolves, new concerns may arise about differences in access. About 10 percent of households with Internet access now have "broadband"[7] Internet access, primarily a cable modem (50.8 percent) or a digital subscriber line (DSL) (33.7 percent). Wireless and satellite technologies (4.6 percent) and other telephone-based technologies such as integrated services digital network (ISDN) (10.9 percent) account for much lower shares of broadband access. Rural areas lag be-

[7]The term "broadband" as used by U.S. DOC (2000b) includes the two most common technologies, DSL and cable modems, as well as other technologies such as ISDN. These technologies provide significantly faster data transmission, although some applications or connections may be slower than the 200 kilobits per second that the Federal Communications Commission defines as broadband.

hind central cities and urban areas in broadband penetration (7.3, 12.2, and 11.8 percent, respectively). Because broadband access is more expensive than dial-up access, its use probably will be less common in households with lower incomes.

IT Use at Home and in Communities

As the previous discussion illustrates, considerable information is now available about access to the Internet. However, information about the extent, nature, and impact of IT use in the home is more scarce. A review of the literature (National Science Foundation (NSF) 2001a) found that home computing in the 1980s has been analyzed extensively, but the more recent wave of computer adoption and Internet use by households has gone largely unexamined.

Indicators of How People Use Computers. Early research (NSF 2001a) found that home computing was used primarily for education, play, work, and basic word processing. Many early adopters used the computer less than they had initially expected. One long-term study found that nearly one-fifth of families quit using their home computer entirely within 2 years. It is unclear whether this underuse resulted from the inability of the technology to meet family needs, the lack of high-quality software for early computers, or other factors. Studies on early users of home computers found that children tended to use home computers more often and for longer periods than adults, and women and girls used home computers less often and less intensively than men and boys. Although playing games was the most common reason cited by children for using the computer, no one application actually dominated their use; they tended to use the computer about equally for playing games, learning, and writing.

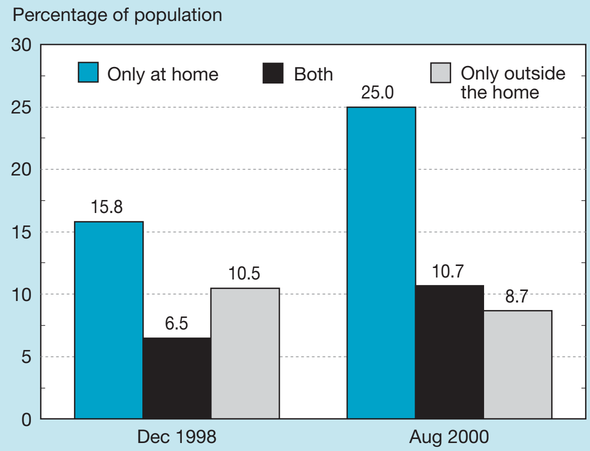
More recent data provide a picture of trends in Internet access at home and outside the home (U.S. DOC 2000b). As shown in figure 8-20, 25.0 percent of the population had access to the Internet only at home as of August 2000, an increase from 15.8 percent in December 1998. The share of the population with access to the Internet both at home and outside the home also increased from December 1998 to August 2000, from 6.5 percent to 10.7 percent. In contrast, the percentage of the population with Internet access only outside the home declined from 10.5 percent to 8.7 percent.

Schools, libraries, and other public access points continue to serve people who do not have access to the Internet at home. For example, certain groups such as unemployed people, blacks, and Asians/Pacific Islanders are far more likely than others to use public libraries to access the Internet (U.S. DOC 2000b).

As shown in figure 8-21, e-mail is the Internet's most widely used application; 79.9 percent of the population used e-mail as of August 2000 and 70.0 percent of the population used e-mail as of December 1998 (U.S. DOC 2000b). Online shopping and bill paying saw the fastest growth in use. In August 2000, 16.1 percent of Internet users reported using the Internet to search for jobs; low-income users were more likely than others to use this application.

Comparison Between Men and Women. The Pew Internet American Life Project (2000) noted that women have been more likely than men to use e-mail to enrich their important relationships and enlarge their networks. In the Pew study, more women than men said they were "attached" to e-mail and pleased with how it helped them. Among women who used the Internet, 60 percent said that e-mail exchanges have improved their connections to family members (compared with 51 percent of men), and 71 percent said that e-mail exchanges have improved their connections with significant friends (compared with 61 percent of men). Among women who said they e-mail friends, 63 percent said they communicated with significant friends more of-

Figure 8-20.
Internet access at home and outside the home: 1998 and 2000



SOURCE: U.S. Department of Commerce. 2000. *Falling Through the Net: Toward Digital Inclusion, A Report on Americans' Access to Technology Tools*. Washington, DC: U.S. Department of Commerce.

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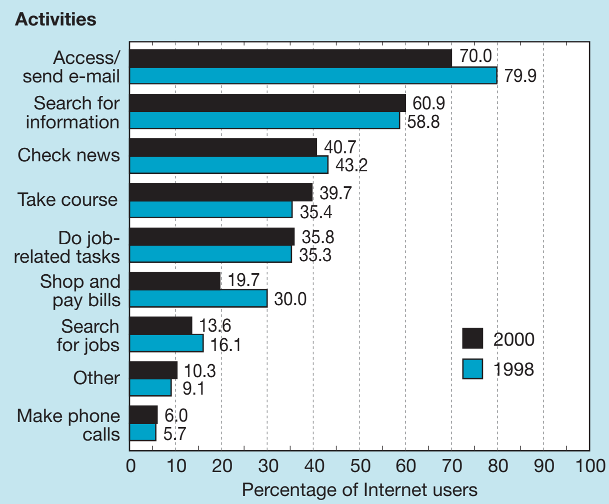
Figure 8-21.
Online activities: 1998 and 2000



SOURCE: U.S. Department of Commerce. 2000. *Falling Through the Net: Toward Digital Inclusion, A Report on Americans' Access to Technology Tools*. Washington, DC: U.S. Department of Commerce.

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ten than they had before they began using e-mail. Among both sexes, e-mail was found to increase communication in some relationships and to be a substitute for conversation in others.

The Pew study also found that women are more likely to go on-line to seek health and religious information, research new jobs, and play games. Men are more likely to go on-line to get news, shop, seek financial information, trade stocks, participate in on-line auctions, access government websites, and search for sports-related news.

On-line Medical Information. One of the top reasons Internet users access the Web is to obtain medical information. Fox and Rainie (2000) found that 52 million adults in the United States, or 55 percent of those with Internet access, have used the Web to get health or medical information. A majority of these users said they go on-line at least once a month for health information. Many said the resources they find on the Web have a direct effect on their decisions about health care and on their interactions with doctors. Among those who use the Internet to obtain health information, 48 percent said the advice they find on the Web has improved the way they take care of themselves, and 55 percent said Internet access has improved the way they get medical and health information. Among this same group, 92 percent said the information they found during their last on-line search was useful; 47 percent of those who sought health information for themselves during their last on-line search said the material affected their decisions about treatments and care.

IT Impact on Families and Individuals. Research into the actual impact of IT on families and individuals is extremely limited in scale and scope (NSF 2001a). However, some research has been conducted on time displacement, telework, psychological well-being, informatics and health care, and the effects of video games on children. The research indicates that use of IT in the home can be both beneficial and harmful. Some findings from this research are highlighted below.

Time Displacement. Home computing and Internet use apparently have not yet substantially displaced other forms of home media and entertainment, such as reading, watching television, or listening to the radio (NSF 2001a). Although some slight displacement of television viewing appears to have occurred, several analysts suggest that PCs and the Internet actually enhance media use because people begin to use other forms of media more often as they develop the habit of acquiring information.

Telework. The research on telework generally predates major changes in distributed work arrangements in large-scale organizations, so the findings from this research may have limited applicability to the contemporary workplace (NSF 2001b). The circumstances of telework have shifted over time. At first, employers allowed telework primarily to permit employees to work from home and more easily manage their family responsibilities. Now, many companies use telework as a strategy to satisfy and retain essential professional, technical, and managerial employees (NSF 2001b).

Studies indicate that telework can demonstrably enhance people's ability to balance work and family needs and reduce personal stress. On the other hand, telework can also disrupt important family dynamics and relationships and create psychological isolation. Most research on telework and distributed work has focused on efficiency and productivity, not on the impacts on individual workers or their families. The effects of telework clearly will differ from situation to situation, depending on whether an individual teleworks full time or only a few days a week, and whether an individual chooses to telework or is compelled to do so by an employer.

Psychological Well-Being. The evidence regarding the impact of computing on the psychological well-being of individuals is mixed. Some data suggest that increased Internet use is associated with social isolation, withdrawal, and stress, although actual Internet "addiction" may be limited to about 10 percent of Internet users and is not necessarily associated with how much time an individual spends on the Internet.

Kraut et al. (1998a) found evidence that increased use of the Internet was associated not only with increased social disconnectedness but also with loneliness and depression. The authors found an association between increased Internet use and "small but statistically significant declines" in social integration (as reflected by family communication and the size of an individual's social network), self-reported loneliness, and increased depression.

Conversely, Katz and Aspden (1997) found no statistically significant differences between Internet users' and nonusers' membership in religious, leisure, and community organizations (their analysis controlled for demographic differences such as age, sex, race, and education). They found that long-term Internet users actually belong to more community organizations than nonusers or former users. In addition, Katz and Aspden found that the vast majority of Internet users (whether recent or long term) reported no change in the amount of time they spent with family and friends on the telephone or in person.

Electronic Government

Like businesses, government agencies have long used IT in management information systems and research. With the advent of the Internet and especially the World Wide Web, however, IT has become a major means of government communication with citizens and other stakeholders. Governments at all levels are rapidly developing new ways of using IT to provide public services to businesses and individuals. Much government information is being made available on-line, and many government activities, from procurement to tax filings, are being conducted on-line.

The Federal Government On-line. The following are a few examples of on-line websites that provide information about the Federal Government (U.S. Working Group on Electronic Commerce 2000):

- FirstGov (<http://www.firstgov.gov>) is a single on-line portal that connects users to all government sites and has one of the largest collections of Web pages in the world. The site allows users to search all 27 million Federal agency Web pages at once.

- The Patent and Trademark Office's X-Search system (<http://www.uspto.gov>) enables anyone to use an Internet browser to search and retrieve, free of charge, more than 2.6 million pending, registered, abandoned, canceled, or expired trademark records. This is the same database and search system used by examining attorneys at the Patent and Trademark Office.
- The National Institutes of Health (NIH) maintains an on-line service (<http://www.ClinicalTrials.gov>) that provides users with information about the latest clinical research on cancer, heart disease, and other life-threatening illnesses.

Federal agencies also are making it possible for citizens to access forms and fill out applications on-line. The Social Security Administration has posted frequently used forms on its website, and individuals can apply for Social Security retirement benefits on-line. The U.S. Department of Agriculture's Forest Service has an on-line reservation system for government-administered campsites nationwide (<http://www.recreation.gov>). In addition, the U.S. Department of Education posts software and documentation for student aid on its website, and the Internal Revenue Service (IRS) posts tax forms and information on its websites and allows taxpayers to file electronically. These are but a few examples of Federal services available on-line.

The Federal Government also uses electronic procurement and payment. The General Services Administration is working toward using e-commerce to make procurement faster and cheaper. One element of this effort is the development of a U.S. Federal Public Key Infrastructure (PKI) to facilitate trusted communication among government agencies, between government agencies and their trading partners, and between the government and the public. PKI verifies the identity of the parties to an on-line transaction, ensures that data have not been altered in transit, prevents a party from falsely claiming that it did not send or receive a particular message, and makes certain that data remain confidential in transit. A number of agencies already have established operational PKIs that can authenticate and protect transactions.

The Federal Government now conducts the vast majority of its financial transactions—collections and expenditures—electronically. The U.S. Department of the Treasury collects electronically more than $1.3 trillion of Federal Government revenue—approximately two out of every three dollars collected (U.S. Working Group on Electronic Commerce 2000). In 1999, the Federal Government made 78 percent of its 959 million payments electronically, including 96 percent of salary payments, 81 percent of vendor payments, and 73 percent of benefit payments.

In addition to websites that offer agency-specific services and information, interagency websites target various segments of the population, such as small business owners, students, and senior citizens. These interagency websites are valuable to citizens because they integrate information across agencies (Fountain 2001a).

Cost Savings From Electronic Government. The cost savings from electronic government are potentially large (Fountain with Osorio-Urzua 2001). Movement from paper-based to Web-based processing of documents and payments typically generates administrative cost savings of roughly 50 percent and more for highly complex transactions (Fountain with Osorio-Urzua 2001).

State and Local Government On-line. State and local governments also are widely deploying electronic government concepts. Many significant reforms related to electronic government applications begin at the state level and then diffuse to Federal and local governments (Fountain 2001b).

Although electronic government services vary widely from state to state, several services are common to a number of states. The most common service, available in 32 states, allows users to find and apply for state government jobs on-line. The second most common service, available in 24 states, is electronic filing for personal income taxes.[8] Other common electronic government services give the public the ability to order vital records (birth, death, and marriage certificates), purchase fishing and hunting licenses and permits, search state government sex offender registries, and renew motor vehicle registrations—all on-line.

A few states offer less typical electronic government services that are both innovative and powerful. For example, North Carolina has three separate portals for citizens, businesses, and employees, with the categories and services offered in each portal oriented toward the type of visitor most likely to use it. Virginia allows users to create a personalized home page by customizing the interface and links to the services and features the user selects.

Local governments at the city, county, and town levels can vary dramatically in the socioeconomic characteristics of their citizenry and in the types of government services they offer. As a result, electronic government at the local level is applied in a variety of ways and with a variety of impacts.

The Indianapolis website (<http://www.IndyGov.org>) is a leading example of municipal government on the Web (Fountain 2001b). Innovative applications include geographical information systems (GIS) services that identify a user's local, state, and national representatives based on the user's address. A wealth of information is available on the Indianapolis website, including maps and descriptions of local recreational facilities. The website also integrates agency and departmental functions into a single, citywide portal.

Contra Costa County, in the San Francisco/San Jose region of California, also uses innovative Web services. The county's animal control department uses a digital camera to photograph stray and lost pets and then posts the photos on the Web, enabling pet owners to take a virtual visit to the pound to search for their lost pets. The county also is developing tools that allow citizens to use GIS data to design their own maps. For example, a resident could access the county Web portal, click on the GIS link, and enter a home address.

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[8]The IRS's e-file program has helped State governments to implement or outsource electronic services easily. The e-file program allows commercial tax preparers to incorporate an Internet filing capability into their tax software and makes it easy for states to adopt systems compatible with e-file and the commercial software.

The individual then could query a number of GIS data sets, including property parcels and values, school locations, police and fire station locations, risk of natural disaster (flood, earthquake, etc.), political districts, and environmental hazards, and quickly produce a customized map that shows all the data requested for the area surrounding the address given.

The Internet also is affecting political processes in the United States and around the world. Political candidates are establishing websites to communicate with voters, solicit funds, and organize volunteers. Interest groups are using e-mail and websites to organize and express their views. In some cases, groups that would be very difficult to organize through traditional means, such as scientists or engineers in different parts of the country, can be mobilized through e-mail to express their views to Congress on a timely issue. Some groups are experimenting with voting via the Internet. See sidebar, “Internet Voting.”

IT and S&E

The S&E community developed IT, in many cases for S&E applications. Scientists and engineers have been among the earliest and most intensive users of many IT applications. It is not surprising that IT has played a major role in the practice of S&E and in the evolution of S&E institutions.

Advances in computing, information storage, software, and networking are all leading to new tools for S&E, ranging from automated scientific instruments to supercomputers for modeling and simulation. IT has made possible new collections of data and new ways to access scientific information. As IT has advanced, applications for S&E have become more powerful and less expensive, and many applications, such as modeling and databases, have migrated from large mainframe computers and supercomputers to desktop computers. IT also has made possible new modes of communication among scientists, allowing them to collaborate more easily. IT affects how research

Internet Voting

Many people have expressed a strong interest in using the Internet to make voting more convenient. It is hoped that such a practice would increase participation in elections. Internet voting is seen as a logical extension of Internet applications in commerce and government. Election systems, however, must meet high standards of security, secrecy, equity, and many other criteria. These requirements make the development of Internet voting much more challenging than most commerce or government applications of the Internet.

The National Science Foundation supported a study and workshop to analyze the issues associated with Internet voting (Internet Policy Institute 2001). The study concluded that remote Internet voting (e.g., voting from the home or office) poses significant risks to the integrity of the voting process and should not be widely used in public elections until substantial technical and social science issues are addressed. On the other hand, it would be possible to use Internet voting systems at polling places, and such systems could offer greater convenience and efficiency than traditional voting systems. Voters could eventually choose to cast their ballots from any one of many polling places, and the tallying process would be both fast and certain. Because election officials would control both the voting platform and the physical environment, managing the security risks of such systems is feasible. Over time, it would also be possible to have Internet voting in kiosks—voting machines located away from traditional polling places—at convenient locations such as malls, libraries, or schools. Kiosk voting terminals pose more challenges than poll-site systems, but most of the challenges could, at least in principle, be resolved through extensions of current technology.

A broad range of research is needed on Internet voting systems. Research topics include the following:

- Approaches to meeting the security, secrecy, scalability, and convenience requirements of elections.
- Development of reliable poll-site and kiosk Internet voting systems that are not vulnerable to any single point of failure and cannot lose votes.
- Development of new procedures for continuous testing and certification of election systems, as well as test methods for election systems.
- Incorporation of human factors into design for electronic voting, including development of appropriate guidelines for designing human interfaces and electronic ballots and development of approaches for addressing the needs of the disabled.
- The economics of voting systems, including comparative analyses of alternative voting systems.
- The effects of Internet voting on participation in elections, both in general and with regard to various demographic groups, especially those with less access to or facility with computers.
- The effects of Internet voting on public confidence in the electoral process and on deliberative and representative democracy.
- The implications of Internet voting for political campaigns.
- Legal issues associated with and the applicability of existing statutes to Internet voting, including jurisdiction, vote fraud, liability for system failures, international law enforcement, and electioneering.